AD NUMBER

AD833230

NEW LIMITATION CHANGE

TO

Approved for public release, distribution unlimited

FROM

Distribution authorized to U.S. Gov't. agencies and their contractors; Administrative/Operational Use; MAY 1968. Other requests shall be referred to Air Force Materials Lab., Wright-Patterson AFB, OH 45433.

AUTHORITY

Air Force Systems Command ltr dtd 2 Mar 1972

1

MECHANICAL PROPERTIES, INCLUDING FRACTURE TOUGHNESS AND FATIGUE, CORROSION CHARACTERISTICS AND FATIGUE-CRACK PROPAGATION RATES OF STRESS-RELIEVED ALUMINUM ALLOY HAND FORGINGS

D. J. Brownhill, C. F. Babilon
G. E. Nordmark and D. O. Sprowls

Contract No. F33615-68-C-1385
Project No. 7381

First Technical Management Report
March 1, 1968 - May 15, 1968

MECHANICAL PROPERTIES, INCLUDING FRACTURE TOUGHNESS AND FATIGUE, CORROSION CHARACTERISTICS AND FATIGUE-CRACK PROPAGATION RATES OF STRESS-RELIEVED ALUMINUM ALLOY HAND FORGINGS

D. J. Brownhill, C. F. Babilon
G. E. Nordmark and D. O. Sprowls

Contract No. F33615-68-C-1385
Project No. 7381

First Technical Management Report
March 1, 1968 - May 15, 1968

NOTICE

ABSTRACT

The scope and testing procedures to be followed in developing the derived mechanical properties, fracture toughness, axial-stress fatigue, stress-corrosion and exfoliation resistance, and fatigue-crack propagation rates of 2014-T652, 2024-T852, 7075-T7352 and 7079-T652 aluminum alloy hand forgings of various sizes are presented herein.

All materials to be tested in the investigation have been ordered.

TABLE OF CONTENTS

		Page
I.	Introduction	1
II.	Scope	2
III.	Material	3
IV.	Procedure	4
V.	Summary	17
VI.	Tables and Figures	18

MECHANICAL PROPERTIES, INCLUDING FRACTURE TOUGHNESS AND FATIGUE, CORROSION CHARACTERISTICS AND FATIGUE-CRACK-PROPAGATION RATES OF STRESS-RELIEVED ALUMINUM ALLOY HAND FORGINGS

I. Introduction.

The design mechanical properties, fracture toughness, corrosion characteristics and fatigue-crack propagation rates are four of the most important factors involved in the selection and efficient design of aerospace structures. The importance of these characteristics has been emphasized by the extensive programs carried out in recent years to develop such information for aluminum alloy plate and extrusions.* Similar data are needed for aluminum alloy hand forgings.

It is particularly timely to give attention to hand forgings, for several reasons: (1) much of the published design data for hand forgings has been obsoleted by a change in the basis of specifying minimum properties, from one in which the length, width and thickness were considered to one in which only the thickness is involved; (2) the development of a technique of stress-relieval by cold work in compression has resulted in relatively new tempers (TX52) for many of the alloys; and (3) there have been some significant problems with forged parts in recent years relatable to fracture and stress-corrosion characteristics.

Accordingly, the properties of hand forgings of several aluminum alloys currently used in aircraft structures are to be determined under this contract. The tests are

* AF33(657)-11155, AF33(615)-2012, AF33(657)-7837, AF33(615)-3580, and F33615-67-C-1521.

intended to provide statistically reliable data for deriving design mechanical properties for MIL-HDBK-5, including stress-strain and compressive tangent-modulus curves. In addition, data concerning the fracture toughness, axial-stress fatigue, stress-corrosion, exfoliation and fatigue-crack propagation characteristics of the materials will be obtained.

II. Scope.

The scope of this program will include the determination of the following properties of 2014-T652, 2024-T852, 7075-T7352 and 7079-T652 hand forgings of the sizes in Table I:

1. The ultimate tensile strength, tensile yield strength, tensile elongation, compressive yield strength, and ultimate double-shear strength in the longitudinal, long-transverse and short-transverse directions at the center of the cross-section of each forging.
2. The ultimate bearing strength and bearing yield strength in the longitudinal and long-transverse directions of each hand forging.
3. The moduli of elasticity in tension and in compression in the longitudinal, long-transverse and short-transverse directions, of representative lots.
4. Tensile and compressive stress-strain curves and compressive tangent-modulus curves for the longitudinal, long-transverse and short-transverse directions of the same lots for which moduli are determined.

5. Plane-strain stress-intensity factor, K_{Ic}, in the longitudinal, long-transverse and short-transverse directions of representative lots.
6. Axial-stress fatigue strengths (stress ratio = 0.0, K_t = 1.0) in the long-transverse direction, of representative lots.
7. Resistance to stress-corrosion cracking in the longitudinal, long-transverse and short-transverse directions and resistance to exfoliation attack, of representative lots.
8. Fatigue-crack propagation rates (R = +0.33) in long-transverse specimens from the 6x24-in. hand forging of each alloy.
9. Fatigue-crack propagation rates (R = +0.33) in longitudinal and short-transverse specimens from the 6x24-in. hand forging of two of the alloys.
10. Fatigue-crack propagation rates (R = +0.33) in long-transverse specimens from the 6x24-in. forging of two alloys tested in (a) dry air, (b) humid air or water, and (c) 3-1/2% salt fog or solution.

III. Material.

The hand forgings to be investigated have been ordered from Alcoa in the alloys, tempers and sizes listed in Table 1. Each of the forgings is to be fabricated independently to represent an individual lot of material. The fabrication history will be reported in as much detail as possible within proprietary and practical limitations.

The sizes of the forgings will represent the range of sizes usually encountered in commercial production with regard to thickness and width/thickness ratio.

The chemical composition of each heat of an alloy will be obtained.

IV. Procedure.

The specimens will be taken in the longitudinal, long-transverse and short-transverse directions from the center region of the cross-section of each forging as shown in Fig. 1.

A. Mechanical Properties

A.1. Tensile, Compressive, Shear and Bearing

The specimens and procedures used will in general be in accordance with ASTM methods and essentially in agreement with Federal Test Method 151.

All tests will be made in testing machines that meet ASTM and Government requirements for accuracy.

All tensile tests will be made in accordance with ASTM Methods of Tension Testing of Metallic Materials (E8-66). The specimens will be 1/2-in. diameter, except where it is necessary to use subsize round specimens (Fig. 8 of ASTM E8-66). Specimens used in the stress-strain tests for the determination of modulus will differ from those, in that the test section will be of uniform diameter.

All compressive tests will be made in accordance with ASTM Methods of Compression Testing of Metallic Materials (E9-67)

and will be made using a subpress (Fig. 3, ASTM E9-61). The specimens will be cylindrical, 1/2 in. in diameter x 1-7/8 in. long (1/r=15), except that for the determination of modulus of elasticity, 3/4-in. diameter x 3-1/2-in. long specimens will be generally used.

Tensile and compressive yield strengths will be determined from load-strain diagrams obtained autographically for each lot in each direction.

The procedures in the tensile stress-strain tests will meet the requirements of ASTM Method for Determination of Young's Modulus at Room Temperature (E111-61) and strains will be measured with a Tuckerman optical strain gage (ASTM Class A). Based on the various tests, typical and minimum tensile and compressive stress-strain and compressive tangent-modulus curves will be developed using the same procedures previously used on the contracts for plate and extrusions. These procedures are in accordance with those outlined in Sections 3.2.3, 3.2.5 and 3.2.6 of Technical Report AFML-TR-66-386.*

Tests to determine ultimate shear strength will be made with 3/8-in. diameter specimens from the same locations as in the tensile tests, except that tests of short-transverse specimens will be made only on forgings 3 in. or more in thickness. The tests will be made with an Amsler double-shear tool in which a 1-in. length is sheared from a specimens 3 in. long, the end thirds being supported throughout their lengths. In

* D. P. Moon and W. S. Hyler, "MIL-HDBK-5 Guidelines for Presentation of Data," Technical Report AFML-TR-66-386, February 1967.

the tests of longitudinal and long-transverse specimens, the loads will be applied in the direction normal to the major forged surface of the forging from which the specimen was taken; in tests of short-transverse specimens, the loads will be applied in the direction parallel to the major axis of the forging.

Bearing tests will be made in accordance with ASTM Methods E238-64T, using longitudinal and long-transverse sheet-type edgewise specimens, 0.094 in. thick x 1-1/2 in. wide, with a 0.375-in. diameter hole and edge distances of 1.5 and 2.0 in. diameter. Before making these tests, the test fixture and specimens will be cleaned ultrasonically in a suitable nontoxic solvent (Toson 3, Giannini Controls Corp.). The bearing yield strength will be determined as the stress at a permanent deformation of 2 per cent of the pin diameter as indicated on autographic load-deformation diagrams.

A.2. Statistical Analysis

To establish statistically acceptable design values for each of the individual mechanical properties of the various alloys, tempers and thickness ranges in each direction, by means of direct statistical analyses of data, would require an amount of testing that would be beyond the limitations of the contract. Therefore, it is planned, as has been the policy of MIL-HDBK-5 in the past and as was done in previous contract work on plate and extrusions, to use the minimum values in the material specification as basis-property "A" or "S" values for the long-transverse tensile properties of each alloy, temper and thickness range. The design values for other properties will be

obtained by applying ratios developed from this contract work to the long-transverse tensile "A" or "S" values. If appropriate, "B" values will be obtained in a similar manner.

The testing to be done in this investigation will lead to ratios of various properties of each individual lot to the long-transverse tensile properties of the same lot, (e.g., ratios of F_{su} (L)/F_{tu} (LT), F_{cy} (L)/F_{ty} (LT), etc.). The ratios determined in the individual tests will be analyzed statistically, and a regression analysis of each group of ratios will be made to determine whether a significant correlation exists with thickness. By applying the ratios resulting from the analyses to the "A", "B" and "S" values mentioned in the preceding paragraph, satisfactory design values for the other properties can be obtained as indicated in "MIL-HDBK-5 Guidelines for the Presentation of Data", Technical Report AFML-TR-66-386.

A. 3. Fracture Toughness

Notch-bend fracture toughness tests will be made using fatigue-cracked notched specimens of the types shown in Fig. 2. The dimensions of the specimens, the chevron notching, fatigue cracking, and the test procedures will be essentially in accordance with the Draft Recommended Practice developed by ASTM E-24*, but incorporating the latest thinking of the authors of that practice as endorsed at the March 13, 1968 meeting of Committee E-24, Subcommittee I. The setup for fatigue cracking the specimens is shown in Fig. 3; the fracture toughness test-setup is shown in Fig. 4. Candidate values of the critical

---

* ASTM Recommended Practice for Plane-Strain Fracture-Toughness Testing of High-Strength Metallic Materials Using a Fatigue-Cracked Bend Specimen, Letter Ballot Draft, May 9, 1967; Revised September 1967.

plane-strain stress-intensity factor, K_Q, will be calculated, using two values of load from the fracture toughness tests. The first value will be calculated using the load at the initial burst (if any) of unstable crack growth, as indicated by the initial significant deviation from linearity in the load-deformation curve. The second value will be calculated using the load at a 5 per cent secant offset, equivalent to about 2 per cent of crack extension; this value is currently defined as K_{Ic} if the following criteria are met:

(a) The plastic zone size must be small with respect to the thickness, as indicated by the limitation that the thickness of the test specimens must be equal to or greater than 2.5 times the ratio $(K_Q/\sigma_{YS})^2$, and

(b) any deviation from linearity in the load-deformation curve prior to the load used for the K_Q calculation must primarily represent crack extension, as indicated by the limitation on the load-deformation diagram that the horizontal displacement of the load-deformation (from the initial slope) at a load 80 per cent of that at the 5 per cent secant offset intercept shall not be more than 1/4 of the displacement at the 5 per cent secant-offset intercept.

A.4. Axial-Stress Fatigue

The axial-stress fatigue strengths will be determined with specimens of the design in Fig. 5 in Krouse fatigue machines operating at 1725 rpm. The stress-levels will in

general correspond to those used on previous contracts involving plate and extrusions.

B. Corrosion Characteristics

The general scope of the corrosion tests is given in Table I; five of the ten hand forgings of each alloy and temper were selected for test. In all aspects of the corrosion studies, liberal use will be made of metallographic techniques to identify and document the types of fracture obtained.

B.1. Exfoliation Resistance

Susceptibility to exfoliation in aluminum alloys is most prevalent in products which have a grain shape that is very thin, wide and long. This sort of grain shape is not usually found in forgings and, in general, exfoliation of aluminum forgings has not been a problem in service. Instances of exfoliation in service have been reported, however; consequently a few tests will be made to permit comparison of forgings with plate and extrusions. The 2x8-in. hand forging was selected as being the shape most likely to be susceptible. Tests will also be conducted with the 6x24-in. hand forging.

Two panels, 4x6 in. in size, from each forging, will be exposed at a 45 degree angle to acidified salt spray. One panel will be machined to a depth equal to 10 per cent of the forging thickness to represent a slight amount of machining and the other panel will be machined to the centerline of the thickness (T/2 plane) to simulate extensive machining.

The salt-spray tests will be carried out in cabinets designed to meet the requirements of ASTM's acidified salt-spray test (B117). The length of exposure will be two weeks and the panels will be inspected daily for extent of attack. Test conditions will be the same as those required by ASTM B117, with the exception that the operating temperature will be 120 F rather than 95 F and specimens will be intermittently sprayed in six-hour repetitive cycles (3/4 hour spray, 2 hour dry-air purge, plus 3-1/4 hours at 100 per cent relative humidity); these changes were introduced because it has been found that they are more conducive to the development of exfoliation attack than the conventional ASTM tests. The specimens will be analyzed visually and microscopically after exposure to establish the type of attack.

B. 2. Resistance to Stress-Corrosion Cracking

The resistance to stress-corrosion cracking of susceptible aluminum alloy-tempers is most critical in the short-transverse direction; consequently, all five forged shapes listed in Table I will be stress-corrosion tested in this direction. In addition, the 2, 4 and 6-in. thick hand forgings will be tested in the longitudinal and long-transverse directions; these additional tests are proposed because forgings represent the aluminum alloy product most likely to be susceptible to stress-corrosion cracking in the other directions as a result of the erratic grain flow patterns.

The short-transverse specimens will be 1/8-in. diameter tensile specimens of the type shown in Fig. 6. Longitudinal and

long-transverse specimens will be 0.437-in. diameter tensile specimens of the type in Fig. 7. Both types of specimens are stressed in frames of the general type shown in Fig. 8. Specimens will be taken about the centerline of the forging thickness.

The stress levels employed in the tests will be varied with the relative resistance to stress-corrosion cracking; this is known from previous tests to be dependent upon both the direction of testing and the alloy and temper. Longitudinal and long-transverse tests of all alloys and tempers will be made at 75 per cent of the tensile yield strength. Long-transverse tests of certain alloy-tempers will also be made at 50 per cent of the tensile yield strength. Dependent upon alloy and temper, the short-transverse tests will be made at either: (a) 75 per cent of the tensile yield strength, (b) 75 and 50 per cent of the tensile yield strength, or (c) 7.5, 15 and 22.5 ksi. The stress levels to be used on the respective alloys are shown in Table II. In all cases, the stresses in the specimens will be determined from deformation (strain) measurements made while the side bars of the fixture (Fig. 8) are forced inward. All stressed tests will be made in triplicate. In addition, duplicate control specimens will be exposed without stress.

The corrosive environment will be 3.5 per cent (by weight) NaCl solution (reagent grade salt and distilled water) conforming to the purity and pH requirements of Method 811 of Federal Test Method Standard No. 151, at room temperature, by alternate immersion. The alternate-immersion cycle is provided by equipment such as that shown in Fig. 9 and consists of 10

minutes of total immersion, followed by aeration above the solution for the remaining 50 minutes per hour, 24 hours per day. The exposure period will be 26 weeks for longitudinal and long-transverse and 12 weeks for short-transverse specimens. The specimens will be visually examined daily for failure and representative failed specimens will be examined microscopically to determine the nature of failure. Specimens that do not fail during exposure will be tested in tension to determine the loss in strength as compared with the unstressed control specimens.

B.3. Special Stress Corrosion Tests On 6x6-Inch 7075-T7352 and 7079-T652 Forgings

In most uniform shaped, rectangular aluminum products the longitudinal, long-transverse and short-transverse grain directions correspond to the physical length, width and thickness of the part. This relationship between grain orientations and physical dimensions does not always hold for hand forgings. Because of the extensive upsetting and kneading operations they receive, hand forgings may have a complex grain flow pattern (Fig. 10). This is particularly true for large square shapes. Specimens can be taken parallel to any of the forged surfaces and by properly positioning them in the cross-section, be made to contain a long-transverse, transverse or short-transverse grain structure. Extensive machining of such forgings into finished parts can likewise expose various grain structures which bear no relationship to the physical dimensions of the forging. Consideration of this variation in grain structure through the cross-section is not crucial for alloy-temper combinations which are highly resistant to stress-corrosion cracking but is very

important for susceptible alloy-tempers. The following tests of the 6x6-in. 7075-T7352 (highly resistant) and 7079-T652 (susceptible) hand forgings are planned to demonstrate this effect.

Full cross-section slices (3/8 in. in length) will be obtained and macroetched to reveal the grain structure. Tensile specimens (0.125 in. diameter) will then be taken parallel to one another but appropriately positioned in the cross-section so that they contain three different grain structures. The resistance to stress-corrosion cracking will then be evaluated in 3.5% NaCl by alternate immersion at a stress of 75 per cent of the tensile yield strength for a 12-week exposure period.

C. Fatigue Crack Propagation

C.1. Preliminary Investigation

The specimen to be used for determination of the fatigue crack propagation rates for longitudinal and long-transverse specimens is shown in Fig. 11. It utilizes a sharp notch instead of the milder notch (Fig. 12) used for previous crack-propagation investigations of plates and extrusions. The sharper notch will increase the uniformity of the crack initiation and thus increase the useful portion of the specimen width over which meaningful data can be obtained. Also the sharper notch should affect the rate of propagation less than the rounded notch in the early stages but the notch change should not be a factor for longer cracks. Four long-transverse 2014-T652 specimens having each notch will be tested to study the effect of the notch geometry on the crack propagation.

Fig. 13 shows the type of specimen to be used for determining the crack propagation rate for short-transverse specimens. It is expected that the short test section length will affect the rate of crack propagation. Accordingly, four long-transverse 2014-T652 specimens will be prepared having this geometry. A comparison of the rates for the two lengths of specimens will be used in the subsequent evaluations of the effect of specimen orientation.

Work at the Naval Research Laboratories and elsewhere, using relatively thin, wide specimens has suggested that it is possible to run "programmed stress patterns" on each specimen: i.e., after the propagation rate, $\frac{\Delta 2a}{\Delta N}$, has been established at the initial stress, the load is increased and another rate is measured, and so forth. Eight long-transverse 2014-T652 specimens will be prepared to determine if this method is feasible for this geometry of specimen. If successful, this method will be utilized for some of the program indicated below and, accordingly, some tests carried out in three or four alloys instead of only two.

C.2. Effect of Stress, Stress Intensity and Strain

Crack propagation rates will be determined at maximum* net stresses of 9.9, 15, and 21 ksi, using long-transverse specimens of all four alloys. The highest loading should produce high local plastic strains at the crack tips. In a few

* Stress Ratio $= \frac{\text{Minimum Stress}}{\text{Maximum Stress}} = 1/3$

of these tests the strain distribution around the crack tip will be observed by stress coat and/or measurements of local thinning or interferometer techniques.

C.3. Effect of Grain Orientation

These large forgings involve six principal specimen orientations as illustrated in Fig. 14. The effect of grain orientation on crack propagation rate will be studied for at least two of the four alloys. It is expected that the alloys investigated will be those having the slowest and fastest crack propagation rates for the long-transverse specimens. However, the selection may be influenced by the industry interest in the alloys at the time. Specimens will be prepared from all the directions indicated. To study the effect of grain run out, specimens having their axis 15° off the longitudinal axis of the forging will also be prepared.

C.4. Effect of Environment

The preceding tests will all be made in ambient conditions. Because the humidity can influence the rate of propagation, three series of tests will be made on two alloys in controlled atmospheres as follows:

1. Dry Air - The central test section will be enclosed in a chamber and the humidity controlled to 30± 10%.
2. Humid Air - Water vapor (or water) will be introduced into the chamber surrounding the central test section so that the humidity is maintained greater than 93%.

3. Salt Fog - A 3-1/2% NaCl salt fog (or solution) will be introduced continuously into the specimen chamber at a rate so that the humidity is greater than 93%.

C.5. Test Procedures

Most fatigue crack propagation tests will be made in 50 000-lb structural fatigue machines of the types shown in Fig. 15, at a rate of 310 cpm. In most tests in ambient air the crack propagation will be measured using a magnifying glass and a scale graduated in hundredths of an inch (because the fatigue cracks advance on a convex front in these thick specimens, more precise measurements generally do not seem justified). This method will probably not be suitable for the controlled environment studies, so an alternate procedure will be developed early in the program. Among the techniques being considered are telescopic surface viewing; surface crack propagation gages, electrical potentional measurements, compliance clip gages and time lapse photography.

For those tests performed in ambient air, the humidity will be continuously recorded and the range of humidities reported for each specimen.

To study the effect of rate of loading, several of the specimens subjected to salt fog will be tested at a rate of 20 cpm.

C.6. Analysis

The method of analyzing the data is being developed. Initially, the crack length will be plotted linearly against

some function of the length. Crack propagation rates will then be determined for each specimen using a computer analysis of the data. These rates will be plotted as functions of the stress intensity and, in some cases, as a function of the strain range (ratio: crack tip plastic strain divided by normal elastic strain). The anticipated forms of crack growth analysis are illustrated in Fig. 16.

An electron microscope will be used to measure striation spacing at several crack lengths for a few representative specimens. The crack propagation rates determined from these spacings will be compared with those determined by external measurements.

V. Summary.

The 40 samples of 2014-T652, 202[illegible]52, 7075-T7352 and 7079-T652 aluminum alloy hand forgings of the sizes to be tested in this investigation have been ordered from Alcoa but none have been received to date.

D. J. Brownhill
D. J. BROWNHILL

C. F. Babilon
C. F. BABILON

G. E. Nordmark
G. E. NORDMARK

D. O. Sprowls
D. O. SPROWLS

r3

VI. Tables and Figures.

TABLE I

TEST PROGRAM FOR DETERMINING THE PROPERTIES OF STRESS-RELIEVED ALUMINUM ALLOY HAND FORGINGS

Alloy and Temper	Thickness Range, in.	Size, in.	No. of Lots	Tensile Autographic L	Tensile Autographic LT	Tensile Autographic ST	Tensile Stress-Strain* L	Tensile Stress-Strain* LT	Tensile Stress-Strain* ST	Compressive Autographic L	Compressive Autographic LT	Compressive Autographic ST	Compressive Stress-Strain* L	Compressive Stress-Strain* LT	Compressive Stress-Strain* ST	Shear L	Shear LT	Shear ST	Bearing Edgewise e/D=1.5 L	Bearing Edgewise e/D=1.5 LT	Bearing Edgewise e/D=2.0 L	Bearing Edgewise e/D=2.0 LT	Notch Bend Fracture Toughness L	Notch Bend Fracture Toughness LT	Notch Bend Fracture Toughness ST	Smooth Axial Fatigue LT	Stress Corrosion L	Stress Corrosion LT	Stress Corrosion ST	Exfoliation L	Fatigue Crack Growth L	Fatigue Crack Growth LT	Fatigue Crack Growth ST
2014-T652	≤ 2.000	2x8	1	1	1	1	1	1	--	1	1	1	1	1	--	1	1	--	1	1	1	1	3	3	--	3	5	8	11	2	--	--	--
	2.001-3.000	3x12	1	1	1	1	--	--	--	1	1	1	--	--	--	1	1	1	1	1	1	1	3	3	--	--	--	--	11	--	--	--	--
	3.001-4.000	4x8	1	1	1	1	1	1	--	1	1	1	1	1	--	1	1	1	1	1	1	1	--	--	--	3	--	--	--	--	--	--	--
		4x16	1	1	1	1	--	--	--	1	1	1	--	--	--	1	1	1	1	1	1	1	3	3	3	--	5	8	11	--	--	--	--
	4.001-5.000	5x5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	--	--	--	--	--	--	--	--	--	--	--
		5x10	1	1	1	1	--	--	--	1	1	1	--	--	--	1	1	1	1	1	1	1	--	--	--	3	--	--	--	--	--	--	--
		5x20	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	3	3	3	--	--	--	11	--	--	--	--
	5.001-6.000	6x6	1	1	1	1	--	--	--	1	1	1	--	--	--	1	1	1	1	1	1	1	--	--	--	--	--	--	--	--	--	--	--
		6x12	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	--	--	--	3	--	--	--	--	--	--	--
		6x24	1	1	1	1	--	--	--	1	1	1	--	--	--	1	1	1	1	1	1	1	3	3	3	--	5	8	11	2	6	34†	6
2024-T852	≤ 2.000	2x6	1	1	1	1	1	1	--	1	1	1	1	1	--	1	1	--	1	1	1	1	3	3	--	3	5	5	8	2	--	--	--
	2.001-3.000	3x12	1	1	1	1	--	--	--	1	1	1	--	--	--	1	1	1	1	1	1	1	3	3	--	--	--	--	8	--	--	--	--
	3.001-4.000	4x8	1	1	1	1	1	1	--	1	1	1	1	1	--	1	1	1	1	1	1	1	--	--	--	3	--	--	--	--	--	--	--
		4x16	1	1	1	1	--	--	--	1	1	1	--	--	--	1	1	1	1	1	1	1	3	3	3	--	5	5	8	--	--	--	--
	4.001-5.000	5x5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	--	--	--	--	--	--	--	--	--	--	--
		5x10	1	1	1	1	--	--	--	1	1	1	--	--	--	1	1	1	1	1	1	1	--	--	--	3	--	--	--	--	--	--	--
		5x20	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	3	3	3	--	--	--	8	--	--	--	--
	5.001-6.000	6x6	1	1	1	1	--	--	--	1	1	1	--	--	--	1	1	1	1	1	1	1	--	--	--	--	--	--	--	--	--	--	--
		6x12	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	--	--	--	3	--	--	--	--	--	--	--
		6x24	1	1	1	1	--	--	--	1	1	1	--	--	--	1	1	1	1	1	1	1	3	3	3	--	5	5	8	2	6	8	6
7075-T7352	≤ 2.000	2x6	1	1	1	1	1	1	--	1	1	1	1	1	--	1	1	--	1	1	1	1	3	3	--	3	5	5	5	2	--	--	--
	2.001-3.000	3x12	1	1	1	1	--	--	--	1	1	1	--	--	--	1	1	1	1	1	1	1	3	3	--	--	--	--	5	--	--	--	--
	3.001-4.000	4x8	1	1	1	1	1	1	--	1	1	1	1	1	--	1	1	1	1	1	1	1	--	--	--	3	--	--	--	--	--	--	--
		4x16	1	1	1	1	--	--	--	1	1	1	--	--	--	1	1	1	1	1	1	1	3	3	3	--	5	5	5	--	--	--	--
	4.001-5.000	5x5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	--	--	--	--	--	--	--	--	--	--	--
		5x10	1	1	1	1	--	--	--	1	1	1	--	--	--	1	1	1	1	1	1	1	--	--	--	3	--	--	--	--	--	--	--
		5x20	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	3	3	3	--	--	--	5	--	--	--	--
	5.001-6.000	6x5	1	1	1	1	--	--	--	1	1	1	--	--	--	1	1	1	1	1	1	1	--	--	--	--	--	10	5	--	--	--	--
		6x12	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	--	--	--	3	--	--	--	--	--	--	--
		6x24	1	1	1	1	--	--	--	1	1	1	--	--	--	1	1	1	1	1	1	1	3	3	3	--	5	5	5	2	--	6	--
7079-T652	≤ 2.000	2x8	1	1	1	1	1	1	--	1	1	1	1	1	--	1	1	--	1	1	1	1	3	3	--	3	5	8	11	2	--	--	--
	2.001-3.000	3x12	1	1	1	1	--	--	--	1	1	1	--	--	--	1	1	1	1	1	1	1	3	3	--	--	--	--	11	--	--	--	--
	3.001-4.000	4x8	1	1	1	1	1	1	--	1	1	1	1	1	--	1	1	1	1	1	1	1	--	--	--	3	--	--	--	--	--	--	--
		4x16	1	1	1	1	--	--	--	1	1	1	--	--	--	1	1	1	1	1	1	1	3	3	3	--	5	8	11	--	--	--	--
	4.001-5.000	5x5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	--	--	--	--	--	--	--	--	--	--	--
		5x10	1	1	1	1	--	--	--	1	1	1	--	--	--	1	1	1	1	1	1	1	--	--	--	3	--	--	--	--	--	--	--
		5x20	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	3	3	3	--	--	--	11	--	--	--	--
	5.001-6.000	6x6	1	1	1	1	--	--	--	1	1	1	--	--	--	1	1	1	1	1	1	1	--	--	--	--	--	10	5	--	--	--	--
		6x12	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	--	--	--	3	--	--	--	--	--	--	--
		6x24	1	1	1	1	--	--	--	1	1	1	--	--	--	1	1	1	1	1	1	1	3	3	3	--	5	8	11	2	--	6	--
Number of Tests	Totals		40	40	40	40	20	20	12	40	40	40	20	20	12	40	40	36	40	40	40	40	60	60	36	48	60	98	185	16	20§	64	12

* And modulus of elasticity

† Includes tests to verify new notch design and check utility of programmed loadings.

†† Alloy selection for longitudinal and short-transverse specimens and study of effect of environment tentative.

§ Includes 6 specimens having an axis 15° to the longitudinal axis of the forging.

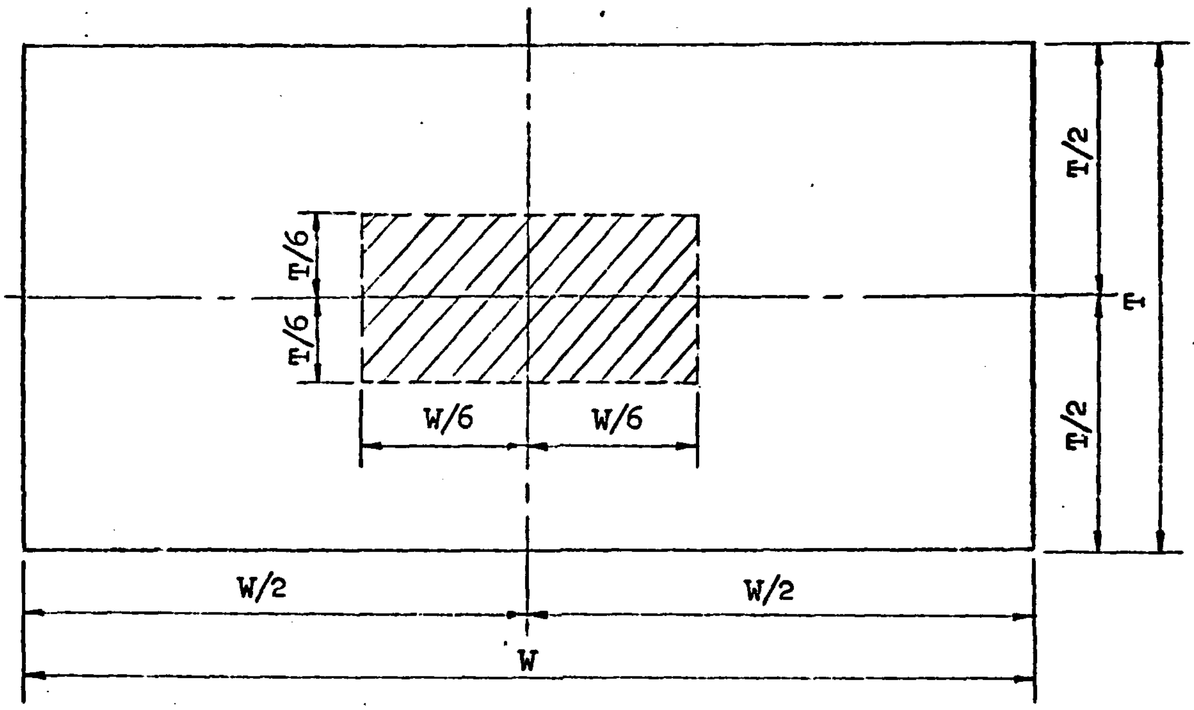
L - Longitudinal
LT - Long-Transverse
ST - Short-Transverse

TABLE II

STRESS LEVELS TO BE EMPLOYED IN STRESS CORROSION TESTS

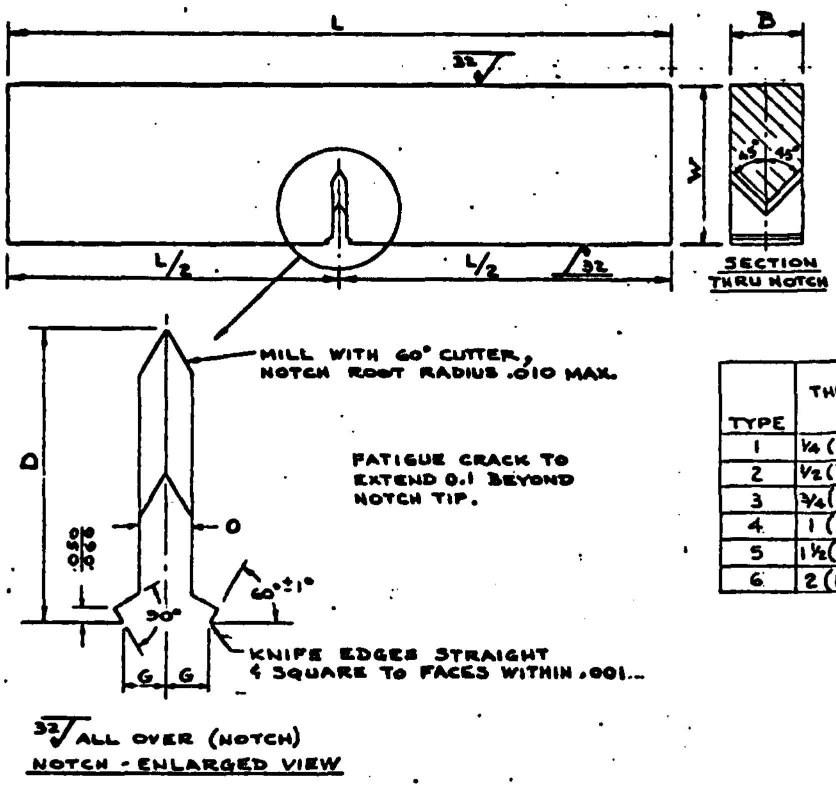
	26 Weeks L Tests	26 Weeks LT or T Tests			12 Weeks ST Tests	
Stress Levels	All Four Alloy-Tempers	2014-T652 7079-T652	2024-T852 7075-T7352	2014-T652 7079-T652	2024-T852	7075-T7352
75% Y. S.	X	X	X	--	X	X
50% Y. S.	--	X	--	--	X	--
22.5 ksi	--	--	--	X	--	--
15.0 ksi	--	--	--	X	--	--
7.5 ksi	--	--	--	X	--	--
Unstressed	X	X	X	X	X	X

Note: L, LT, T and ST refer to longitudinal, long-transverse, transverse and short-transverse directions.



NOTE: Test Sections of All Specimens Will Be Within Center Third of Width and Thickness (cross-hatched area).

Fig. 1 Location of Test Sections of Specimens In Cross-Section of Hand Forgings.



TYPE	THICKNESS IN. B	DEPTH IN. W	SPECIMEN LENGTH IN. L	NOTCH DEPTH IN. D	NOTCH OPENING IN. O	GAP WIDTH IN. G
1	1/4 (3/16-3/8)	See Dwg D-011475-RK				
2	1/2 (7/16-5/8)	1	5	0.40 (±0.01)	1/8 (0.120-0.125)	0.095-0.100
3	3/4 (11/16-13/16)	1 1/2	7	0.65	1/8	
4	1 (7/8-1 3/16)	2	9	0.90	1/8	
5	1 1/2 (1 1/4-1 9/16)	3	13	1.40 (±0.02)	1/4 (0.245-0.250)	0.195-0.200
6	2 (1 3/4-2 1/8)	4	17	1.90	1/4	

Fig. 2 Notch-Bend Fracture Toughness Specimens

Fig. 2

Fig. 3 Cantilever Beam Setup for Fatigue Cracking Notched Bend Fracture Toughness Specimens.

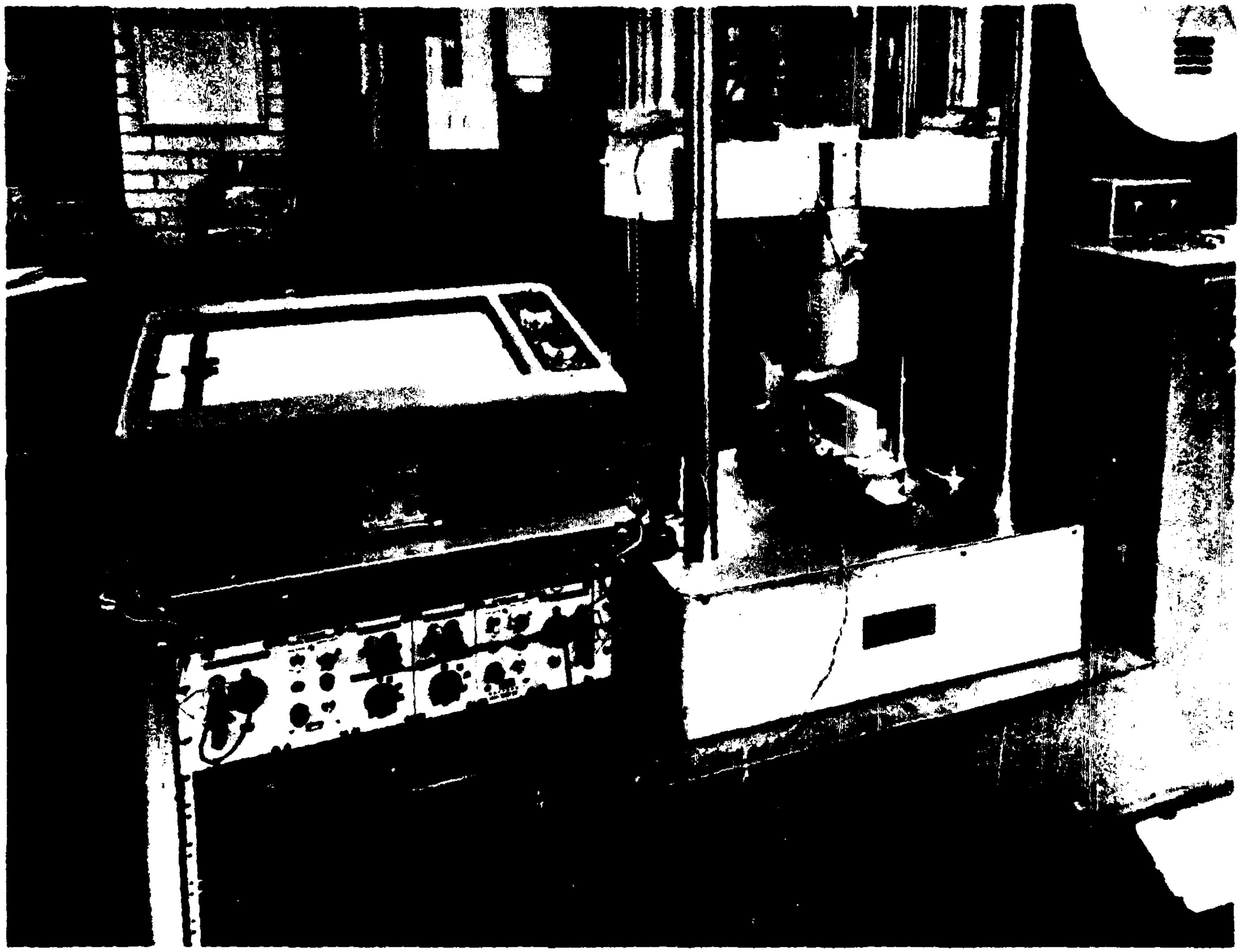


Fig. 4 Setup for Notch-Bend Fracture Toughness Testing.

Fig. 4

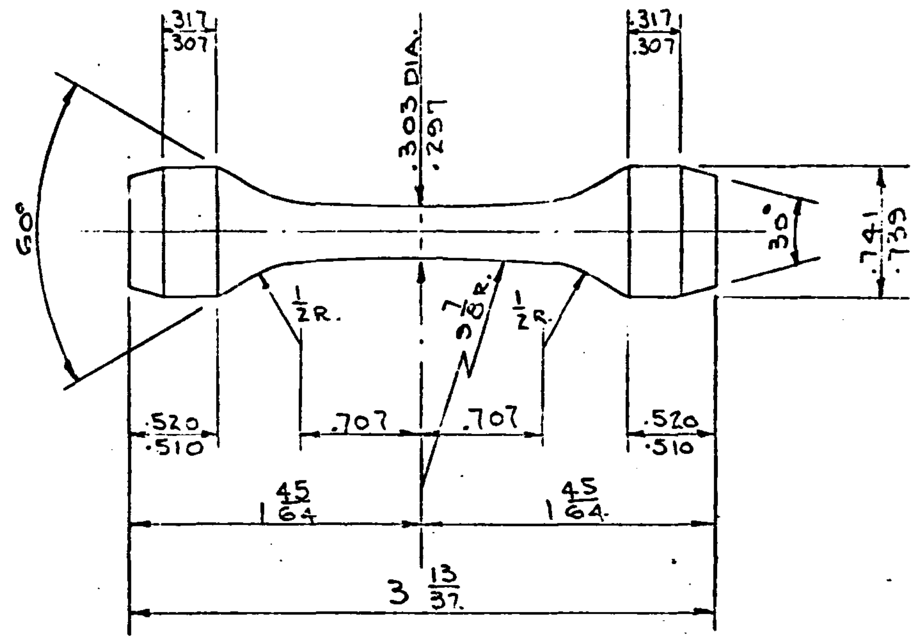


Fig. 5 Axial-Stress Fatigue Specimen

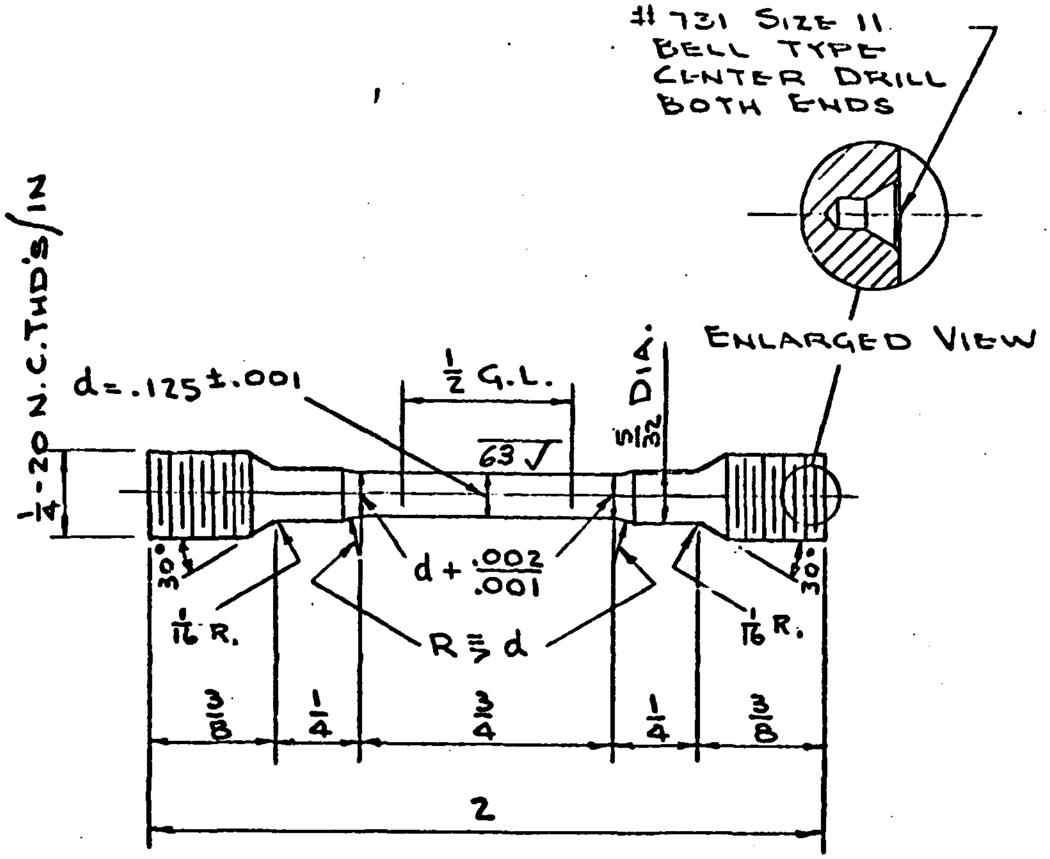


Fig. 6 0.125-in. Diameter Tensile Specimen for Stress Corrosion Tests.

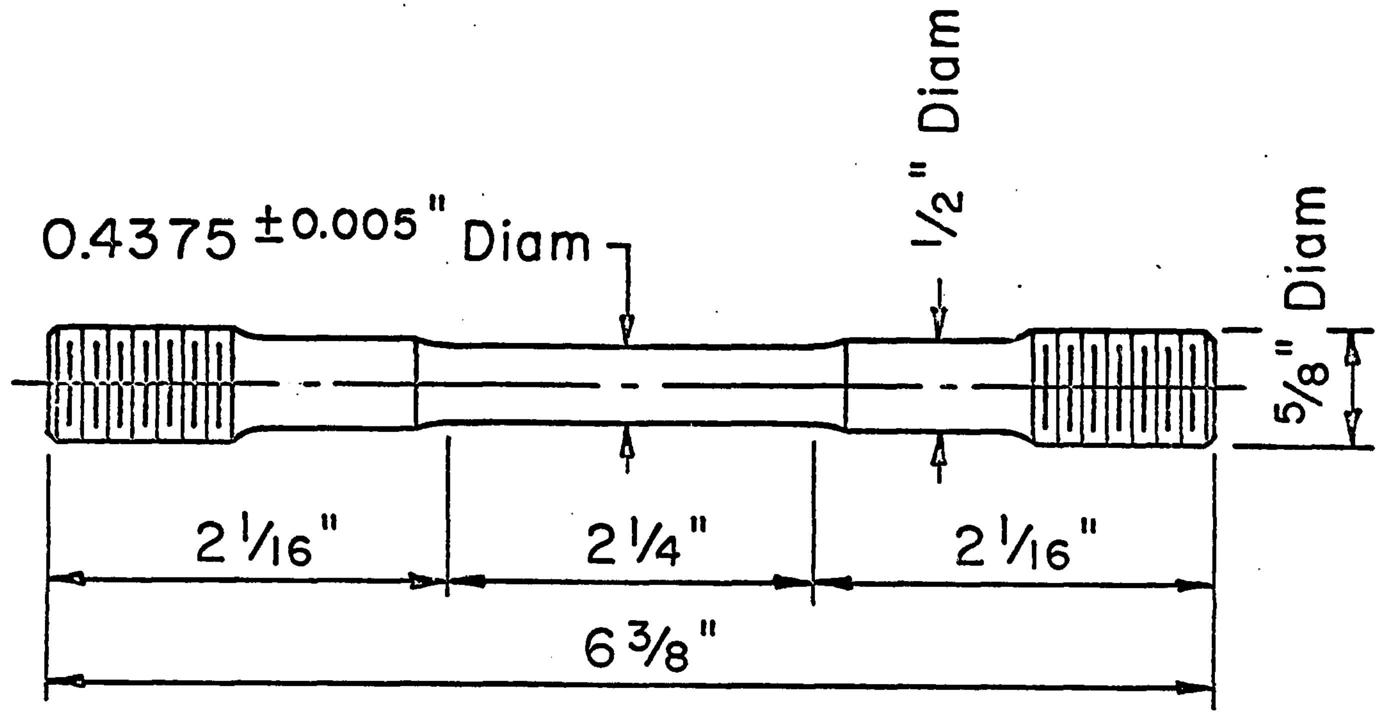


Fig. 7 0.437-in. Diameter Tensile Specimen For Stress Corrosion Tests.

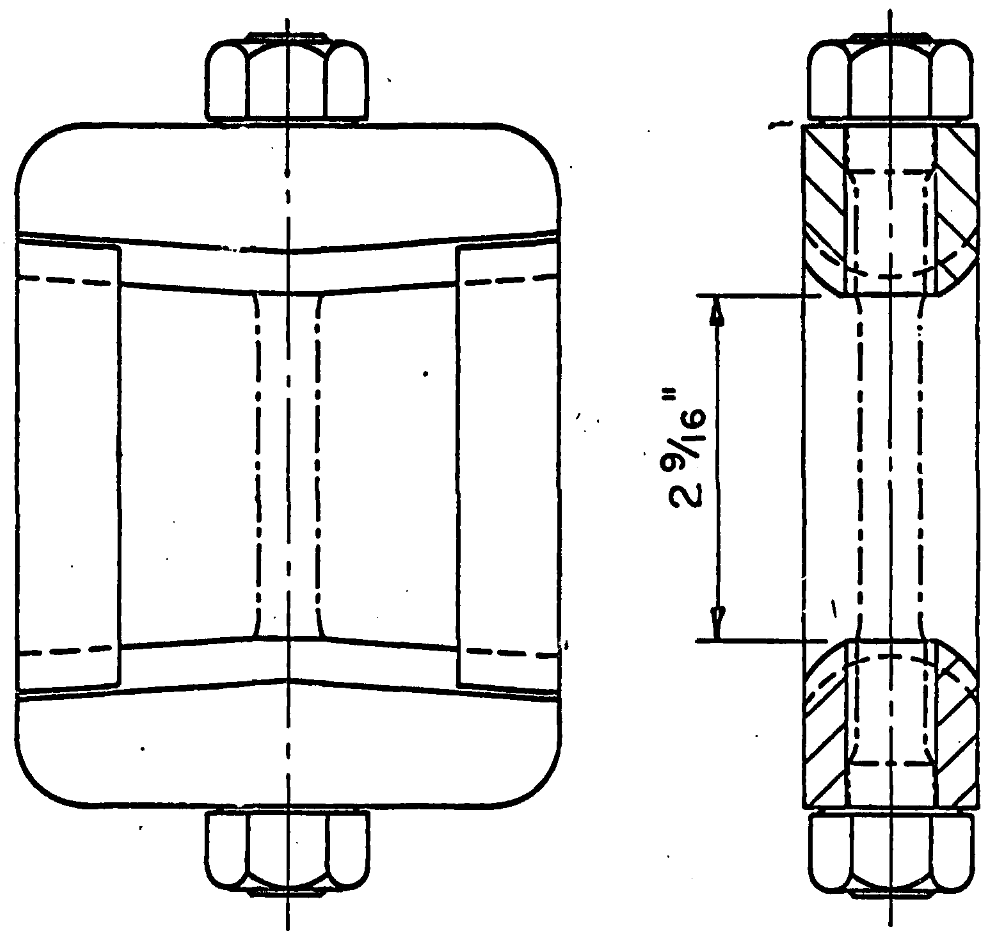


Fig. 8 Stressing Frame for Stress Corrosion Tests of 0.437-in. Diameter Tensile Specimen.

Fig. 9 Alternate Immersion Equipment

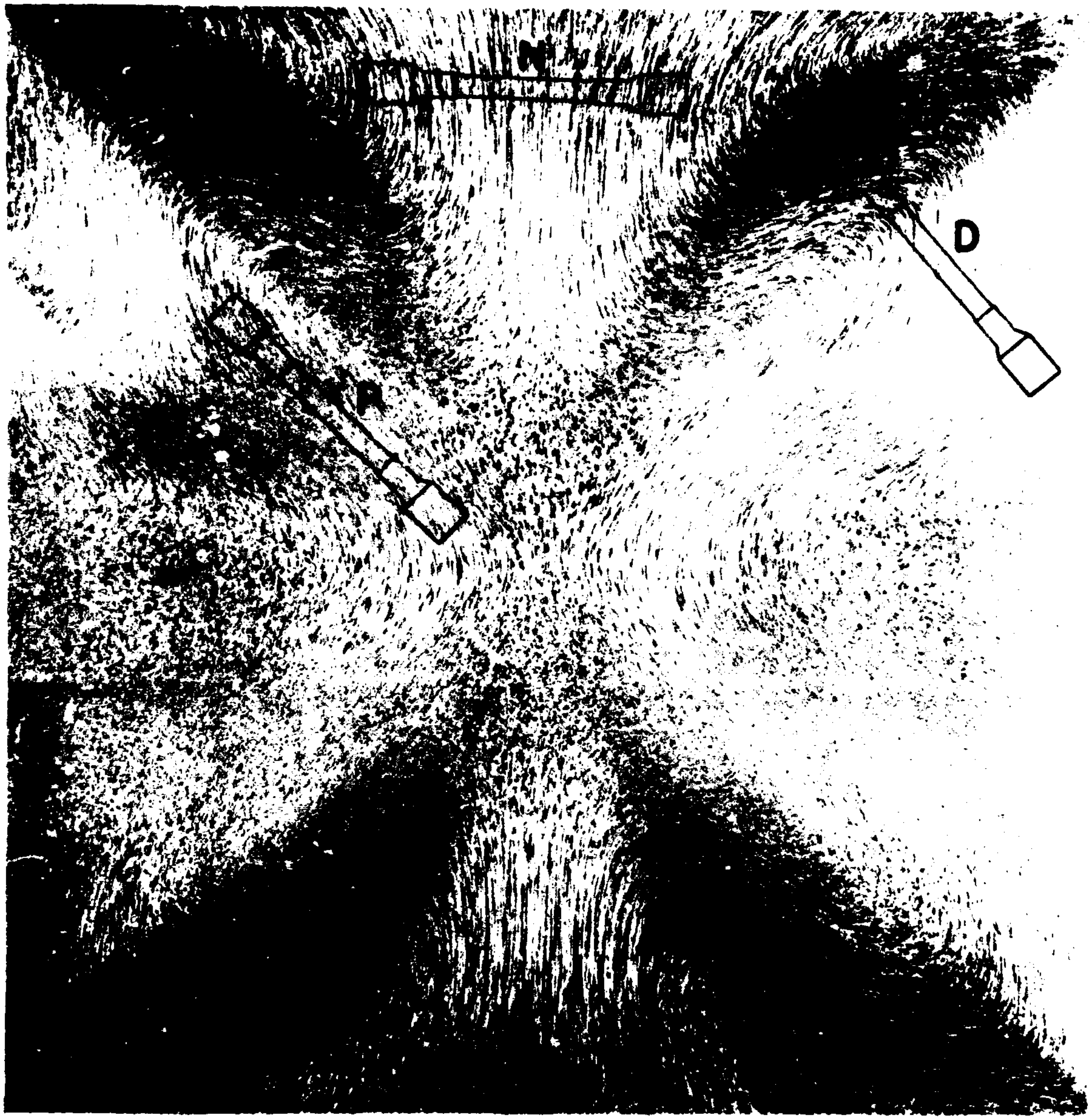


Fig. 10 Photograph of a macroetched transverse section from a large square hand forging showing an X-shaped flow pattern. Tensile specimens can be made to contain grain structures by appropriate positioning in the cross-section as exemplified above. Tests of this sort will be made on the 6x6-in. 7075-T7352 and 7079-T652 forgings to demonstrate the effect on resistance to stress-corrosion cracking.

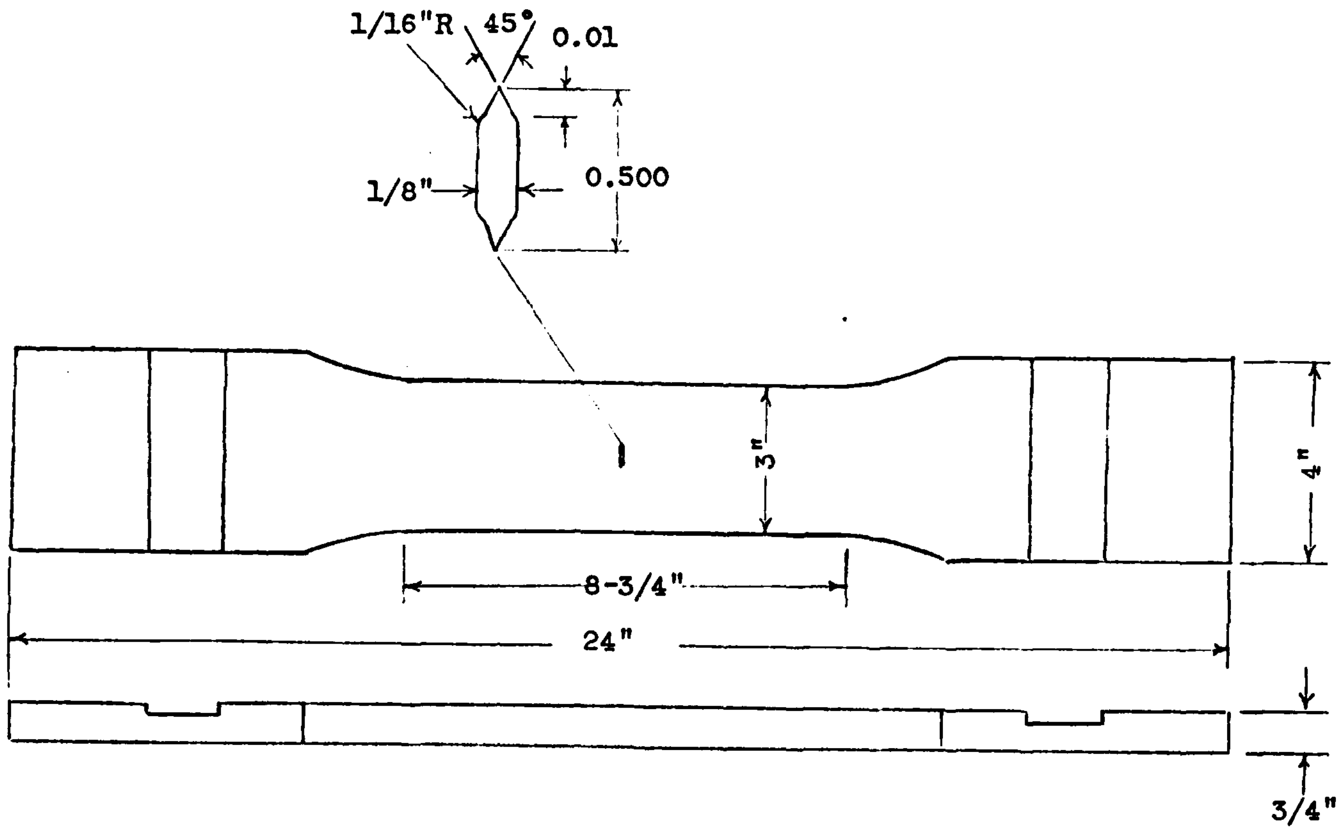


Fig. 11 Center-Notched Fatigue Specimen

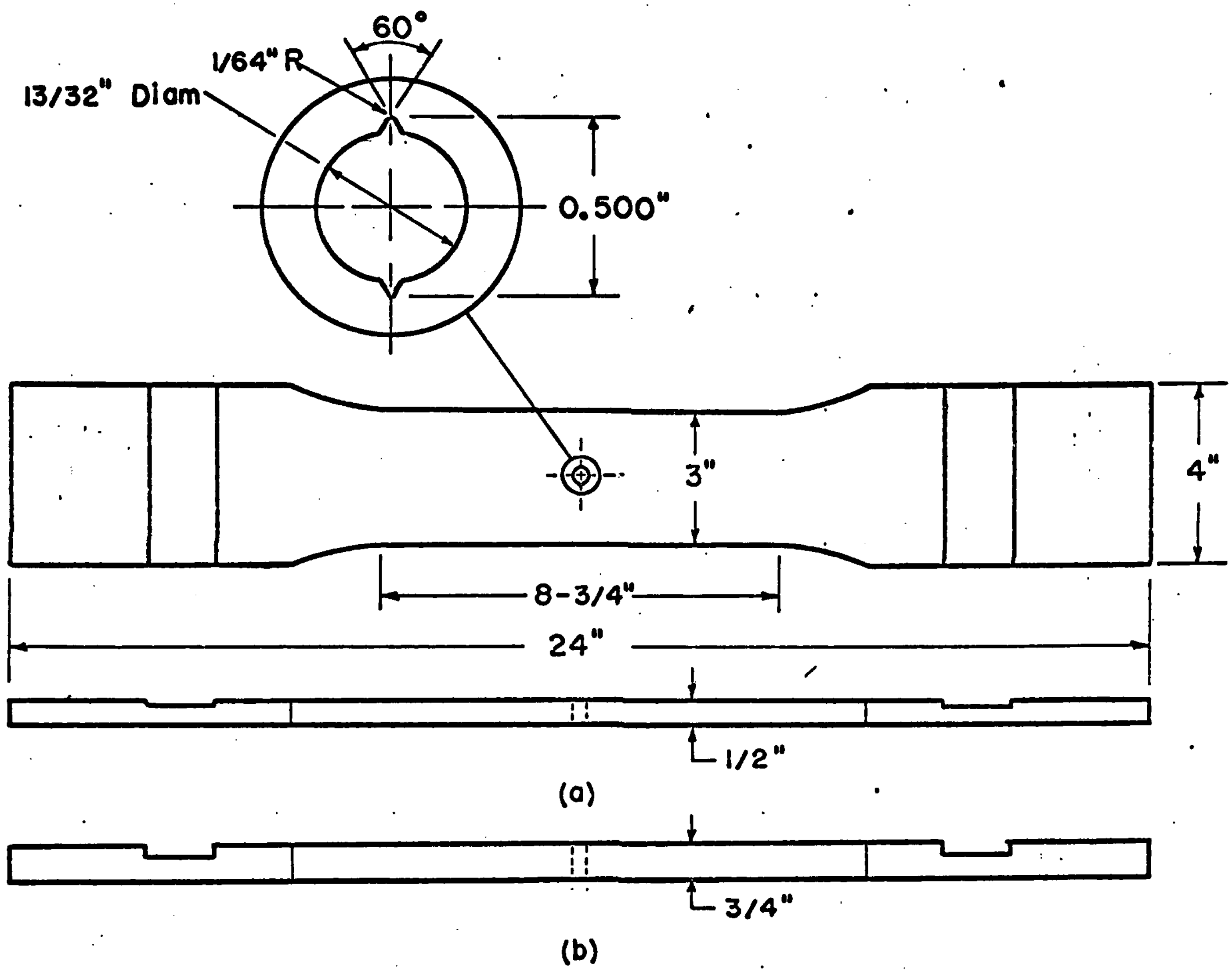


Fig. 12 Center-Notched Fatigue Specimen

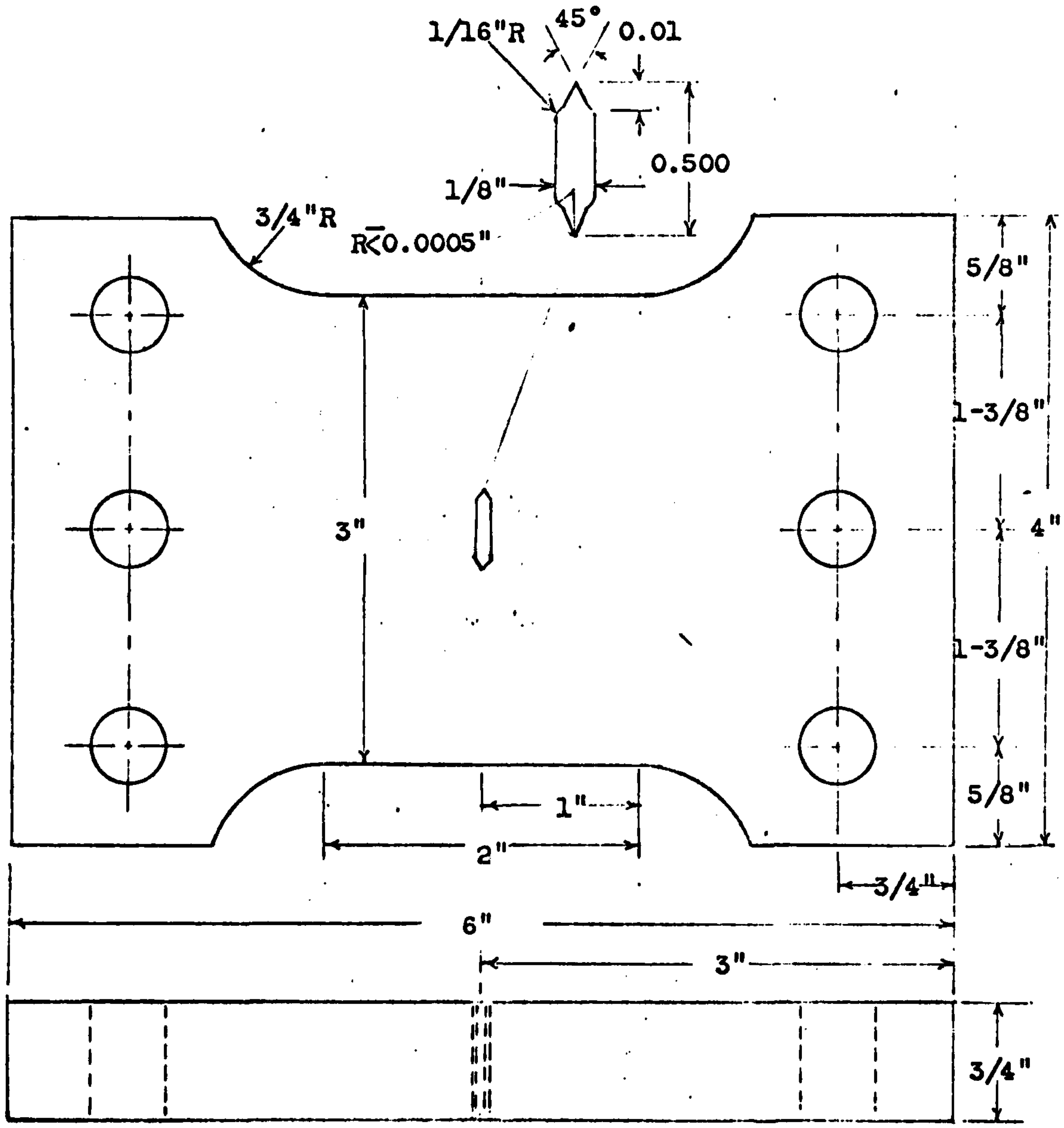
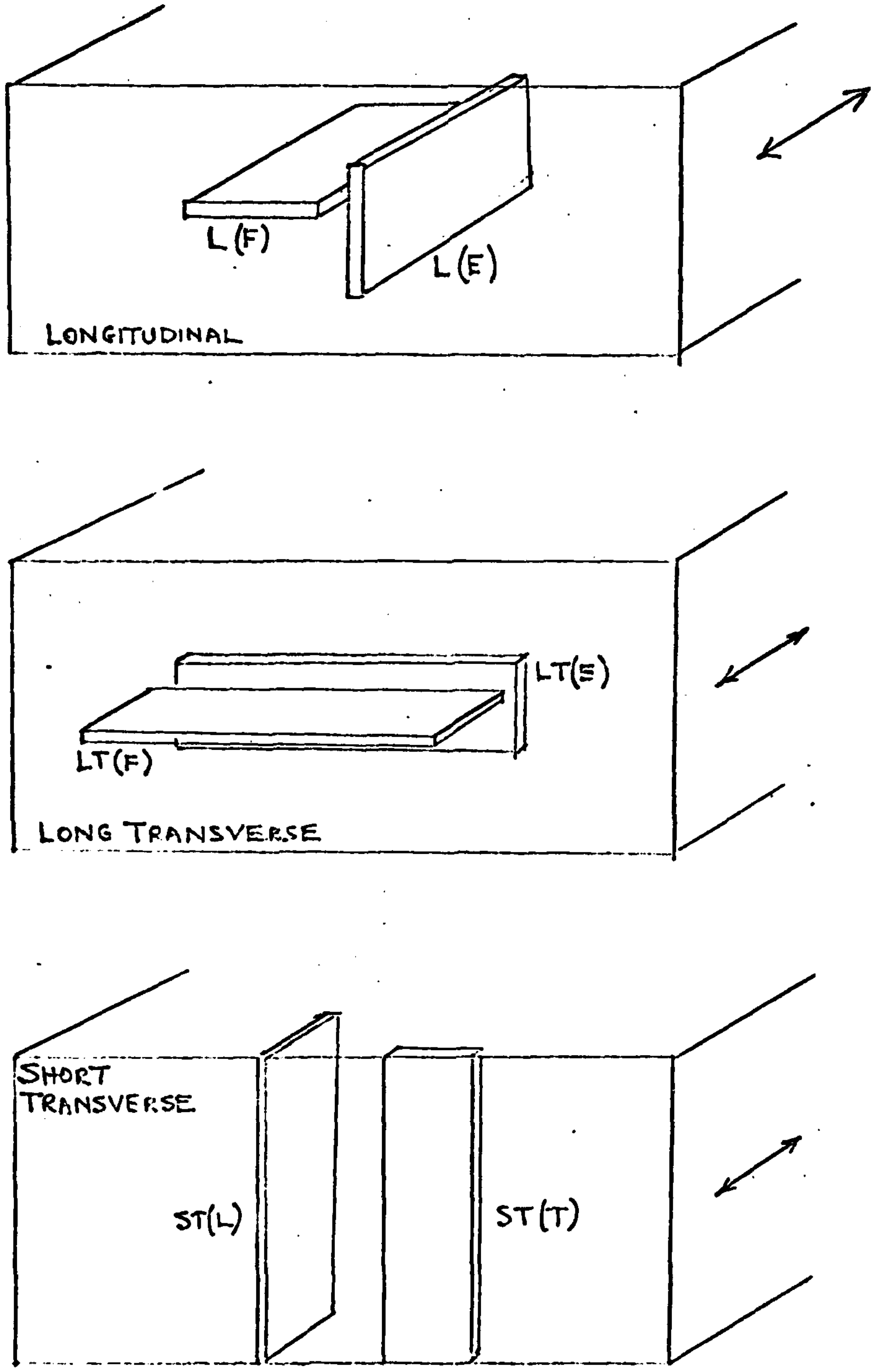


Fig. 13 Short-Transverse Center-Notched Fatigue Specimen



NOTE: The orientation of the specimen to evaluate grain-run-out will be chosen after macroscopic examination of the grain flow patterns of the forgings.

Fig. 14 Orientations of Fatigue Crack Propagation Specimens.

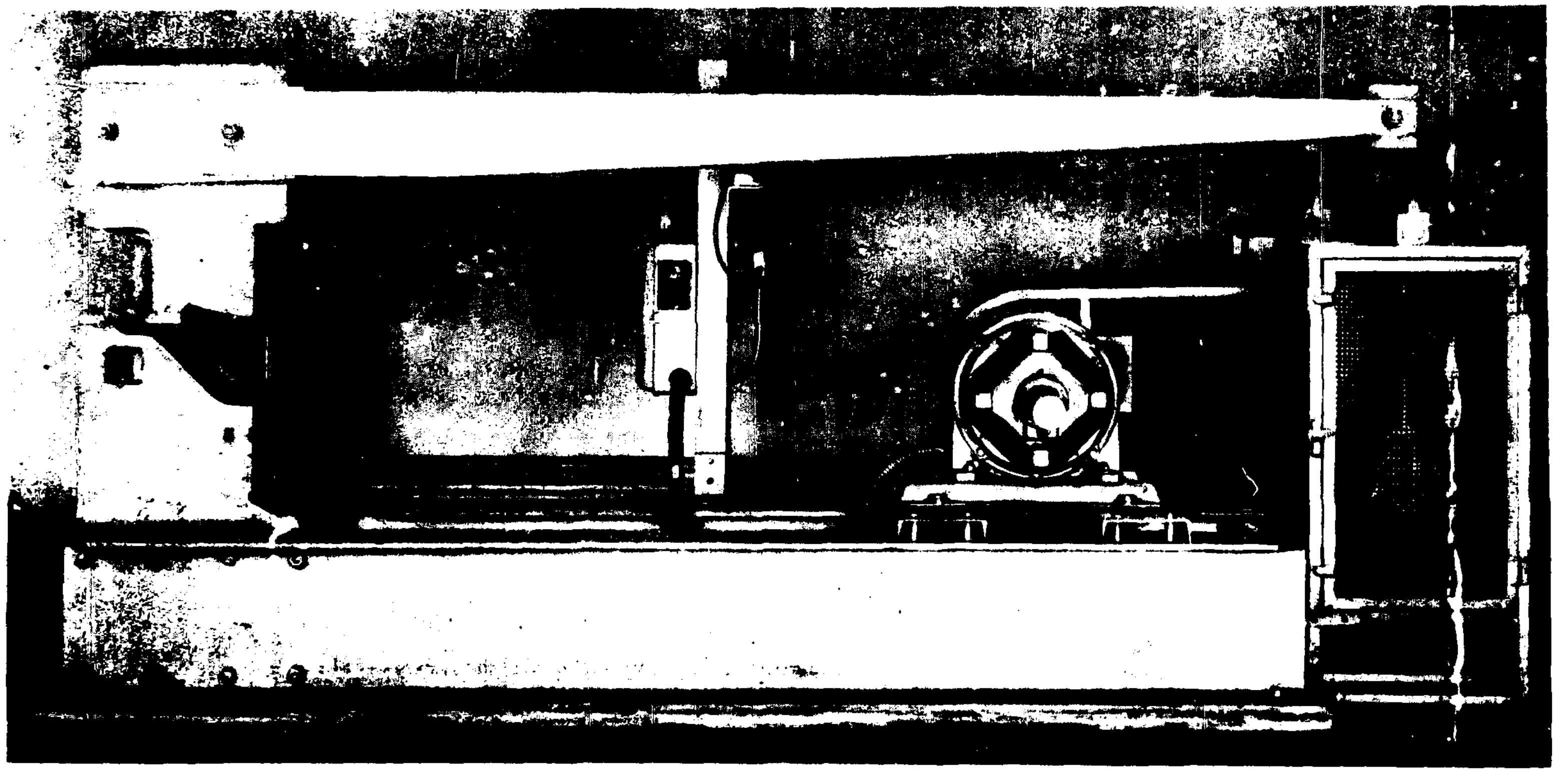


Fig. 15 50,000-lb Structural Fatigue Machine to be Used in Crack Propagation Studies.

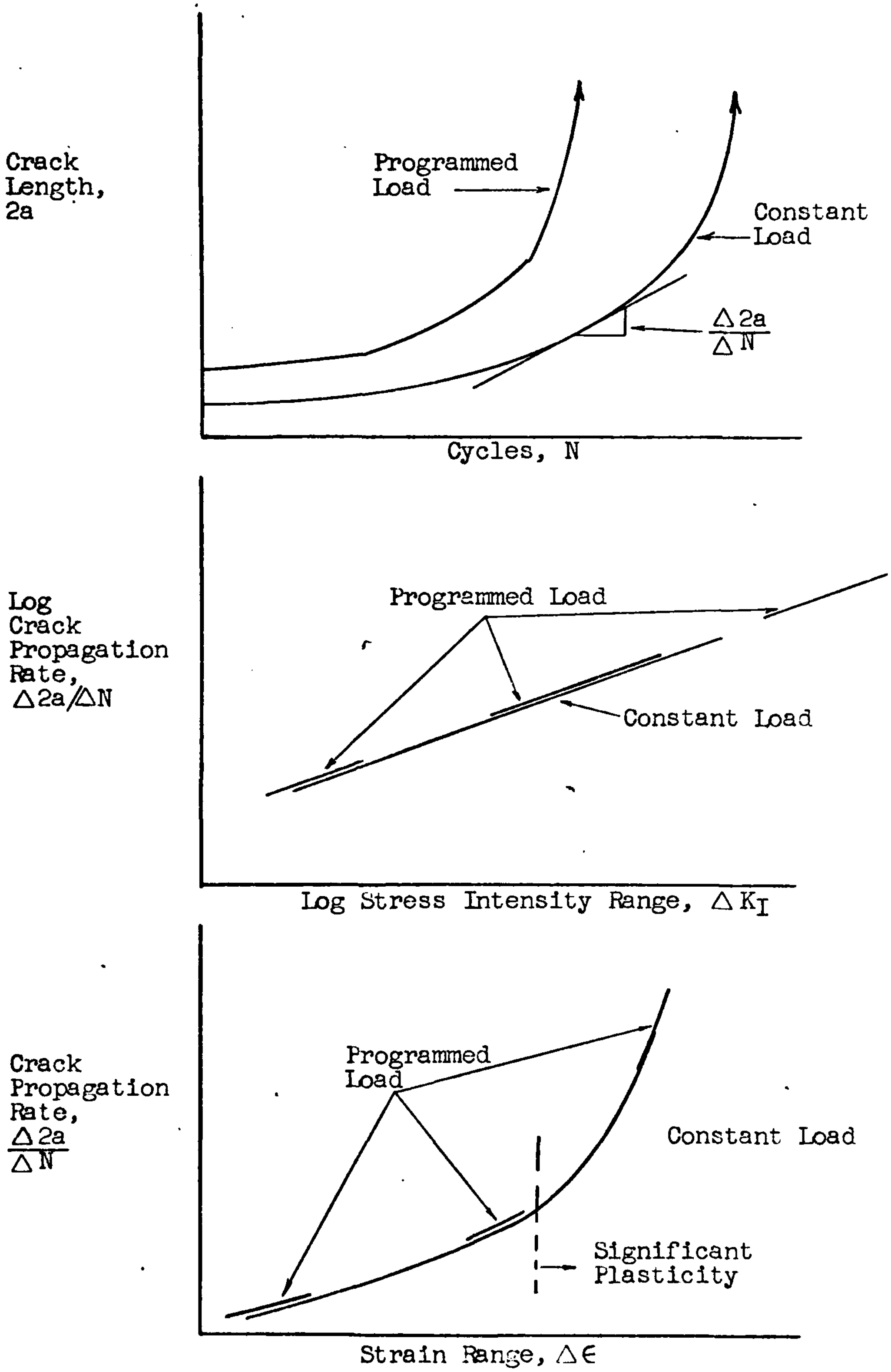


Fig. 16 Illustrative Means of Presenting Fatigue Crack Propagation Data.